DETERMINATION OF ENDPOINTS FOR TMDL DEVELOPMENT FOR MCKAY BAY (WBID 1484B) AND PALM RIVER (WBID 1536E)

March 2013

1.0 Introduction and Objective

The United States Environmental Protection Agency (EPA) prepared a proposed TMDL for nutrients and dissolved oxygen (DO) for Ybor City Drain (WBID 1584A) and McKay Bay (WBID 1584B) in October 2010 (EPA, 2010). The report provided a proposed TMDL for total nitrogen to address impairment of nutrients and DO for McKay Bay and nutrients for Ybor City Drain.

This technical memorandum provides recommended water quality endpoints for McKay Bay for use in development of a revised TMDL for the McKay Bay system, including Ybor City Drain and the tidal Tampa Bypass Canal (TBC) or Palm River. The endpoints are appropriate for supporting the designated uses of the Class III waterbody, which are recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife. This is part of a project being completed for a group of stakeholders including the City of Tampa, the Florida Department of Transportation, Hillsborough County, and Tampa Bay Water, which includes development of a hydrodynamic and water quality model for use in TMDL development for the McKay Bay system.

This task includes a summary of previous work done in the system and in Tampa Bay for establishment of appropriate water quality endpoints, and evaluates the applicability of this work to the current endpoint determination.

2.0 Summary of Previous Work

Several pertinent work efforts have addressed water quality endpoints in McKay Bay and the downstream bay segment of Tampa Bay, Hillsborough Bay (Figure 2-1). Over the last two decades, the Tampa Bay Estuary Program (TBEP) and Tampa Bay Nitrogen Management Consortium (TBNMC) have developed seagrass and commensurate water quality targets and thresholds, as well as Total Nitrogen (TN) loading targets, for the mainstem of Tampa Bay including Hillsborough Bay (Janicki and Wade, 1996; TBEP, 1996a,b; TBEP 2001; TBNMC 2010). Recently, the TBEP has proposed segment-specific TN loading thresholds as potential estuarine numeric nutrient criteria, and provided segment-specific TN concentration thresholds as potential alternative criteria, for all segments of the bay, including Hillsborough Bay (Janicki Environmental, 2011a,b).

In addition to the TBEP and TBNMC efforts, recommended chlorophyll *a* and dissolved oxygen criteria have been recommended specific to McKay Bay and the TBC (Janicki Environmental, 2005a,b). A continuing effort by the Florida Department of Environmental Protection (FDEP) is developing revised DO standards for marine waters. This section provides summaries of these efforts and discusses the applicability of the derived endpoints to the current endpoint determination for use in development of the TMDLs.

Figure 2-1. Location of Tampa Bypass Canal, McKay Bay, and Hillsborough Bay.

2.1 Tampa Bay Targets and Thresholds

The TBEP and TBNMC have previously established seagrass targets, associated water quality targets (light attenuation and chlorophyll), and TN loading targets to the bay. The Comprehensive Conservation and Management Plan (CCMP) of the TBEP (TBEP, 1996a) established seagrass restoration as a primary goal. In establishing and addressing the goal, a conceptual paradigm was developed to identify the primary management factors thought to influence the recovery and sustainability of seagrass resources within the bay (Figure 2-2). As depicted in the TBEP's nitrogen management paradigm, reduced water clarity as a result of excessive nitrogen loads to the bay and resulting light attenuation by phytoplankton responding to these loadings were the key water quality indicators by which seagrass recovery could be managed.

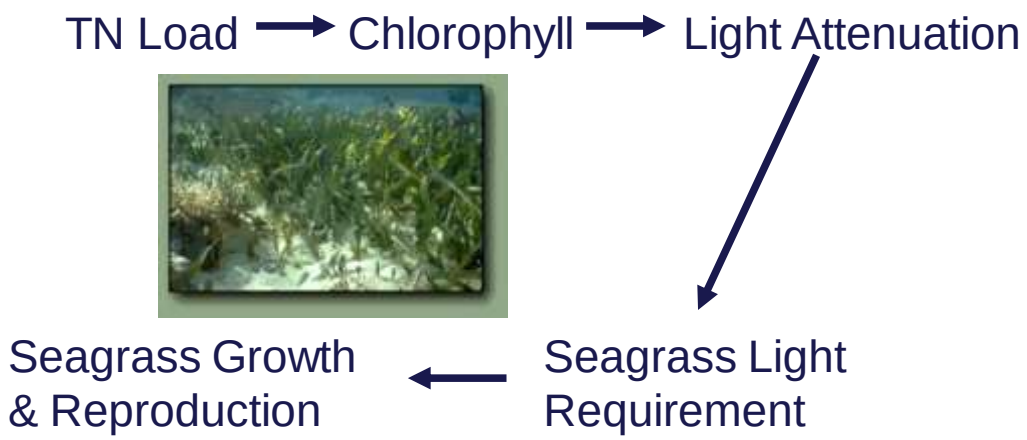

Figure 2-2. Conceptual paradigm describing the nitrogen management strategy employed by Tampa Bay Estuary Program partners to relate nitrogen loading to seagrass response in Tampa Bay.

The seagrass target for Tampa Bay was developed utilizing historical benchmark extents from the circa 1950 time period, estimates of those areas physically altered since the 1950s so that there was no reasonable possibility of these areas supporting seagrasses, and the 1990 seagrass coverage, as described in Janicki and Wade (1996). Development of segment-specific light and chlorophyll *a* targets commensurate with the seagrass targets included derivation of relationships between water quality and light attenuation, and between water quality (chlorophyll *a*) and TN loadings (Janicki and Wade, 1996).

The chlorophyll *a* targets developed from this effort were segment-specific. Potential chlorophyll *a* targets were developed utilizing two methods: the TN loading-chlorophyll *a* relationships, and annual average values from the 1992-1994 period. The TN loading-chlorophyll *a* model was used to identify the chlorophyll *a* needed for sufficient light to reach depths in each segment corresponding to recovery to the seagrass target acreage. Based on improving seagrass coverage and water quality seen over the 1990–1996 period, secondary targets were developed from the average annual chlorophyll *a* levels seen during 1992-1994 (a period of time with high and low rainfall during which seagrass was expanding). The ultimate selection of bay segment-specific chlorophyll *a* targets was determined as the average annual levels developed from the empirical model predictions (Janicki and Wade, 1996) or the 1992-1994 average annual levels – whichever were lower (TBEP, 1996b; 2001).

The TBEP Technical Advisory Committee (TAC) further recognized that there may be years in which these targets may be exceeded without causing significant reductions in seagrass cover. This means that there is some allowable amount of variation that should not elicit a significant degradation in water quality and therefore seagrass coverage. This level of variation was defined as two standard errors around the period of record mean annual chlorophyll *a* concentrations in each segment. Therefore, a distinction is made between a **target**, i.e., a desired chlorophyll *a* concentration, and a **threshold**, i.e., a chlorophyll *a* concentration above which undesirable chlorophyll *a* concentrations exist. The chlorophyll *a* threshold for each segment is the sum of the target and two standard errors around the mean annual chlorophyll *a* concentrations in each segment. These thresholds have been recognized in both the recent WQBEL and RA documents

(FDEP, 2010; TBNMC, 2010). The chlorophyll *a* target and threshold for Hillsborough Bay are 13.2 µg/L and 15.0 µg/L, respectively.

In addition to a chlorophyll *a* threshold for the bay segment downstream of McKay Bay, the TBEP has recently provided numeric nutrient criteria to FDEP for consideration for each segment of Tampa Bay. For each segment, the TBEP has provided both recommended expressions of the criteria and potential alternative expressions. For Hillsborough Bay, one method of expressing the TN criterion is as a concentration-based criterion (Janicki Environmental, 2011a). In keeping with the federally-recognized TMDL TN loading targets for Tampa Bay, derived from the average annual 1992-1994 TN loads, the alternative numeric nutrient criterion in terms of TN concentration for Hillsborough Bay is the sum of the geometric mean 1992-1994 concentration and one standard deviation based on the 1992-2009 data. For Hillsborough Bay, this proposed alternative concentration-based TN criterion is 1.01 mg/L.

2.2 McKay Bay and TBC Targets and Thresholds

2.2.1 Chlorophyll *a*

Existing living resource based site-specific chlorophyll *a* thresholds have been established for waterbodies immediately upstream and downstream of the McKay Bay/TBC system. Upstream of McKay Bay and the tidal TBC, the freshwater portions of the TBC and Upper Hillsborough River are generally represented by the IWR threshold for nutrient impairments of an annual mean chlorophyll *a* of 20 µg/L. Downstream of McKay Bay, chlorophyll *a* thresholds have been established for the estuary system of Hillsborough Bay based on restoration and protection of seagrass, as described above. Seagrass has been mapped historically in McKay Bay, with the circa 1950 coverage being approximately 152 acres (Figure 2-3). As determined from seagrass coverage data provided by the Southwest Florida Water Management District (SWFWMD), which began aerial photography and estimation of seagrass coverage in the late 1980s, very little if any seagrasses are found in McKay Bay. Seagrass transect data collection by the Tampa Bay Interagency Seagrass Monitoring Program (TBISP) City of Tampa Wastewater Department Bay Study Group in McKay Bay (Avery and Johansson, 2010) confirms the scarcity of seagrass in McKay Bay, with maximum seagrass shoot density coverage during the 2000-2008 period less than 5% in any meter square placement during the period.

The loss of the 1950-era seagrasses in McKay Bay is not unexpected, as the TBC was constructed from the Palm River and Six Mile Creek as an Army Corps of Engineers flood control project over the period 1967-1983, with the estuarine segment upstream to S-160 completed in 1969. The TBC was dredged to approximately 7 m depth, straightened, and widened as much as 12 times, with the cross section increased over 100 times in some areas (HDR, 1994; SWFWMD, 2005). Following connection to the Hillsborough River in the mid-70s, the TBC receives water from the Hillsborough River watershed as well when necessary for flood control or water supply. The physical modifications to the TBC and McKay Bay since the late 1960s resulted in a system with much greater freshwater inflows and much greater channel depths than during the 1950s, so it is not surprising that seagrass loss has occurred.

As described in Janicki Environmental (2005a), since seagrass habitat was historically present in McKay Bay, a living resource based approach to developing a chlorophyll *a* threshold was applied.

The TBEP seagrass target and light target were applied to the McKay Bay/TBC system for the living resource based chlorophyll *a* threshold approach. The 1950 McKay Bay seagrass extent is a part of the Hillsborough Bay seagrass target extent identified by the TBEP (Janicki et al., 1995). The TBEP light target for this region is to provide 20.5% of surface light to a depth of 1.0 meter at mean water (Janicki and Wade, 1996). The TBEP light target of 20.5% of surface light was based on a SWFWMD light requirements study (Dixon and Leverone, 1995) and an adjustment for 2% bottom reflectance (Janicki and Wade, 1996). The TBEP depth target of 1.0 meter was based on the depth distribution of 1950 seagrasses.

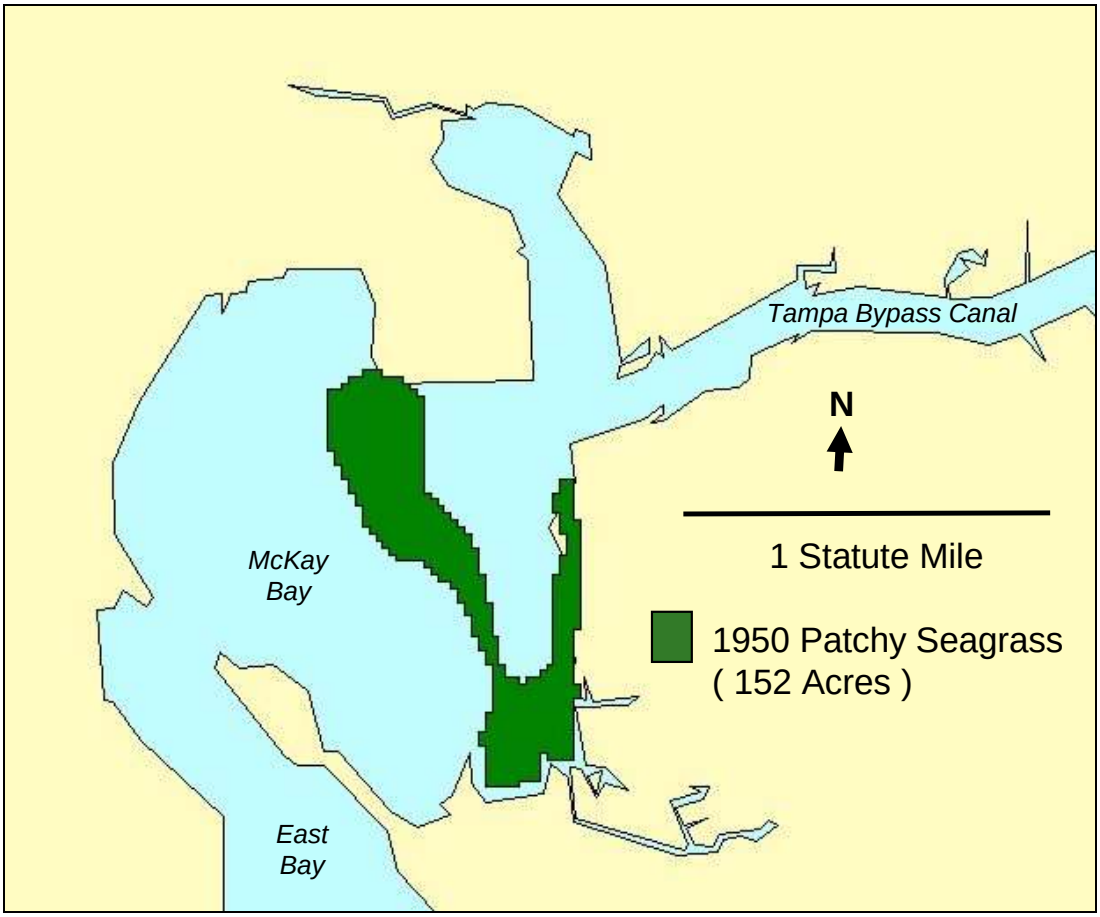

Figure 2-3. The extent of "patchy seagrass" in McKay Bay/TBC system in 1950 (Florida Dept.of Natural Resources and U.S. Fish and Wildlife Svc.).

Following an empirical approach similar to the TBEP chlorophyll *a* target development approach, a living resource based chlorophyll *a* threshold was identified that would result in meeting the target of 20.5% of surface light to 1.0 meter at mean water. Since the Environmental Protection Commission of Hillsborough County (HCEPC) long term water

quality station 58 was located in the vicinity of historical seagrass coverage in the McKay Bay/TBC system, the data from this station were used in the empirical approach.

A least squares regression model was fit to the observed McKay Bay data as follows:

$$ln(Z) = 2.03108 - 0.68495 \times ln(C)$$

where, C = average annual chlorophyll *a* concentration (µg/L), and
Z = average annual water depth to which 20.5% of surface irradiance penetrates (meters at mean water).

The regression model fit the observed data well (R^2=0.71, 28 corrected total degrees of freedom, Pr>F < 0.0001, slope significantly different from zero at Pr>|t|<0.0001) (Figure 2-4).

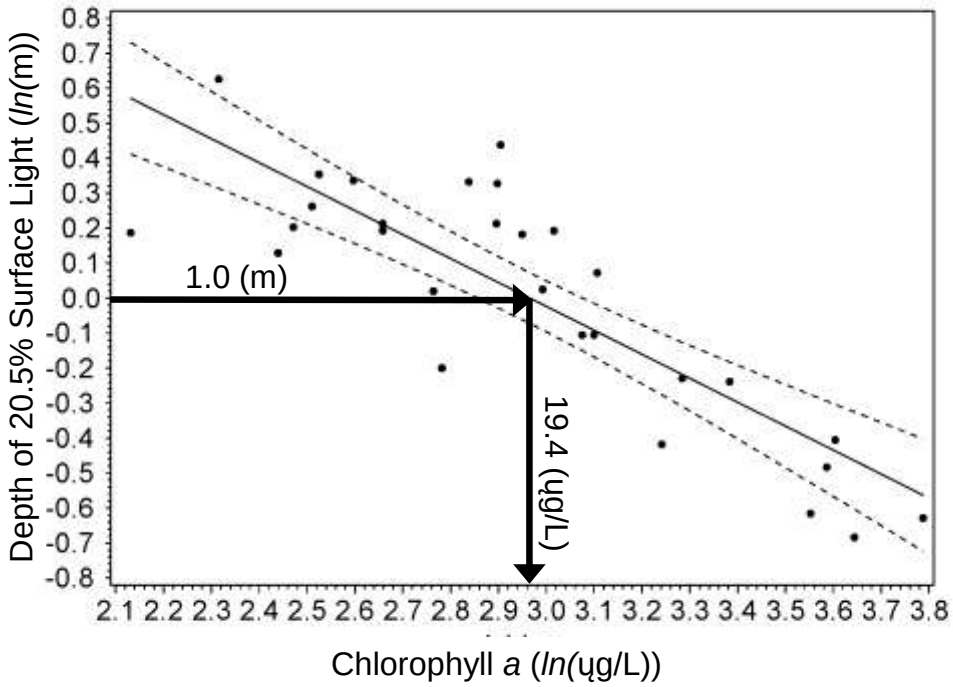

Figure 2-4. Conceptual relationship of light penetration and chlorophyll *a* concentration for McKay Bay EPC Station 58.

The chlorophyll *a* and Secchi disc depth data from 1974 to 2004 from EPC Station 58 were used for the regression analysis presented in Figure 2-4 (Janicki Environmental, 2005a). Secchi disc data for 14 of the 347 monthly observations were excluded from the analysis because the water depth was too shallow to measure Secchi disc depth on those sampling days. Secchi disc data were converted into percent light at depth data using the TBEP reported relationship derived from City of Tampa water quality data (Janicki and Wade, 1996):

$$K_d\ (1/m) = 1.61/\text{Secchi Disc Depth (m)},$$

and

Beer's Law: $I_z = I_0 \times e^{-(Kd)\,z}$

where K_d =the diffuse attenuation coefficient (1/m),
I_z =the light at depth Z in the water,
I_0 = the light just below the surface of the water, and
Z = the depth (m).

Using the regression model described above a living resource based chlorophyll *a* target of an average annual 19.4 µg/L was identified. This chlorophyll *a* target is consistent with meeting the seagrass light target of 20.5% light to a depth of 1.0 meter at mean water in McKay Bay. Based on U.S. Geological Survey bathymetric data, this light target would be met for a total of 174 acres of shallow (<1.0 meter at mean water) habitat currently existing in McKay Bay, with this extent greater than the 152 acres of historically documented seagrass habitat in McKay Bay (Figure 2-3).

The chlorophyll *a* and Secchi disc data were updated through 2009 to re-evaluate the relationship and re-derive the chlorophyll *a* target as a check on the 2005 derivation. Based on this effort, the revised relationship, with an R^2 of 0.61, resulted in a chlorophyll *a* target of 19.5 µg/L, so that the relationship between light attenuation and chlorophyll has not changed.

2.2.2 Dissolved Oxygen

The following presents 3 alternatives for developing the endpoints and method of compliance for dissolved oxygen. These include;

- the present State of Florida criteria for dissolved oxygen in Marine Waters and the States interpretation of compliance assessment under the IWR;
- an alternative DO criteria established for McKay Bay and the TBC as part of the development of the Minimum Flows and Levels (MFL); and
- an alternative DO criteria presently under development by FDEP.

Existing Criteria:

An additional effort was completed to identify alternative dissolved oxygen (DO) criteria for the McKay Bay/TBC estuarine system that are more appropriate given the nature of the system than those provided by the existing statewide criteria, as described in Janicki Environmental (2005b). The existing DO criteria for these waterbodies are:

- 4.0 mg/L minimum instantaneous DO,
- 5.0 mg/L as a 24-hour average, and
- to maintain the normal daily and seasonal fluctuations in DO levels.

Alternate D.O. Criteria:

Janicki Environmental (2005b) developed alternative DO criteria utilizing three independent approaches:

- a quantification of existing DO conditions in a high quality reference system,

- an empirical analysis of the observed relationship between DO and biological integrity, and

- a quantification of the DO requirements of the types of aquatic organisms expected to be found in the McKay Bay/TBC system under suitable water quality conditions.

The DO criteria derived from each of these three independent approaches were developed using relatively extensive datasets of laboratory and field observations of water quality conditions and the types of organisms found in Tampa Bay tidal rivers. For each approach, findings as presented in Janicki Environmental (2005b) were as follows:

- The reference system approach identified that the typical lower DO concentrations, i.e. those occurring in 10% of the days in a year, ranged from approximately 2 mg/L to 4 mg/L.

- The empirical analysis approach identified that fish biological integrity was consistently good at bottom DO levels above 4 mg/L, and it was consistently poor at bottom DO levels below 2 mg/L. Between bottom DO levels of 2 mg/L and 4 mg/L, gradient responses in fish biological integrity were observed. The statistical breakpoint analysis typically identified a value of 2.5 mg/L as the level of maximum change in these relationships.

- The quantification of the DO requirements of aquatic organisms was based on application of the aquatic life based approach developed by EPA for the Virginian Province (EPA, 2000). This approach utilized conservative assumptions with respect to the species included in the analysis, with species removed only if the phylum was absent from the system. The focus of the analysis is on providing a representative range of the expected DO tolerances for estuarine organisms in the system. Laboratory data from a wide variety of organisms that are very sensitive to low DO conditions were utilized to identify the following:

    - for continual DO exposures above 5.0 mg/L no impairment was expected;
    - below a continual DO exposure of 2.1 mg/L an unacceptable mortality rate (i.e., >5%) was expected; and
    - between DO levels of 4.5 mg/L and 2.8 mg/L the effects on biological integrity were expected to depend on the number of days of continual exposure to the DO values.

Alternative DO criteria were expressed as a series of minimum DO thresholds for which no more than 10% of the McKay Bay/TBC system observations over a year should be in exceedance, with multiple DO thresholds each representing a minimum DO value for a given proportion of bottom area or volume. For example, the DO criteria could be expressed (Janicki Environmental, 2005b) as

"No more than 10% of the days in a year should have more than 20% of the bottom area with mean daily DO values less than 2.36 mg/L", or

"No more than 10% of the days in a year should have more than 30% of the river volume with daytime DO value less than 2.98 mg/L".

FDEP Alternate D.O. Criteria:

Recent work by FDEP (2012) has addressed potential modifications to statewide DO criteria for both freshwater and marine waters. For marine waters, FDEP criteria development methods were based on EPA's Virginian Province Approach, which uses measured response of sensitive organisms to low DO environments to establish allowable exposure durations. The potential revised criteria account for three components: 1) Criteria Minimum Concentration (based on 24-hour average) (CMC), 2) Criterion Continuous Concentration (CCC), and 3) Final Larval Recruitment/Survival Curve (FRC).

The CMC was calculated based on the acute effects data for 26 species, with species mean acute values ranging from 0.43 to 2.17 mg/L. The CCC was developed based on larval and juvenile growth bioassay data for 19 species, with species mean chronic values ranging from 1.34 to 4.67 mg/L. The FRC development used ten Florida species, with the larval dose-response curves for the four most sensitive genera used to develop the inhibited growth equation (FDEP, 2011) (Figure 2-5).

The FDEP effort to date has resulted in three levels of potential criteria for marine waters:

- Below 2.8 mg/L, adverse acute impacts are possible;
- Between 2.8 mg/L and 4.9 mg/L, exposure duration based on larval survival response; and
- Above 4.9 mg/L, no impacts expected.

FDEP has chosen to express the potential criteria in terms of DO saturation rather than concentration, as this accounts for the known seasonal (i.e., temperature) effects on the expected DO levels, whereas concentration-based criteria require a fixed minimal DO level be maintained throughout the year regardless of water temperature.

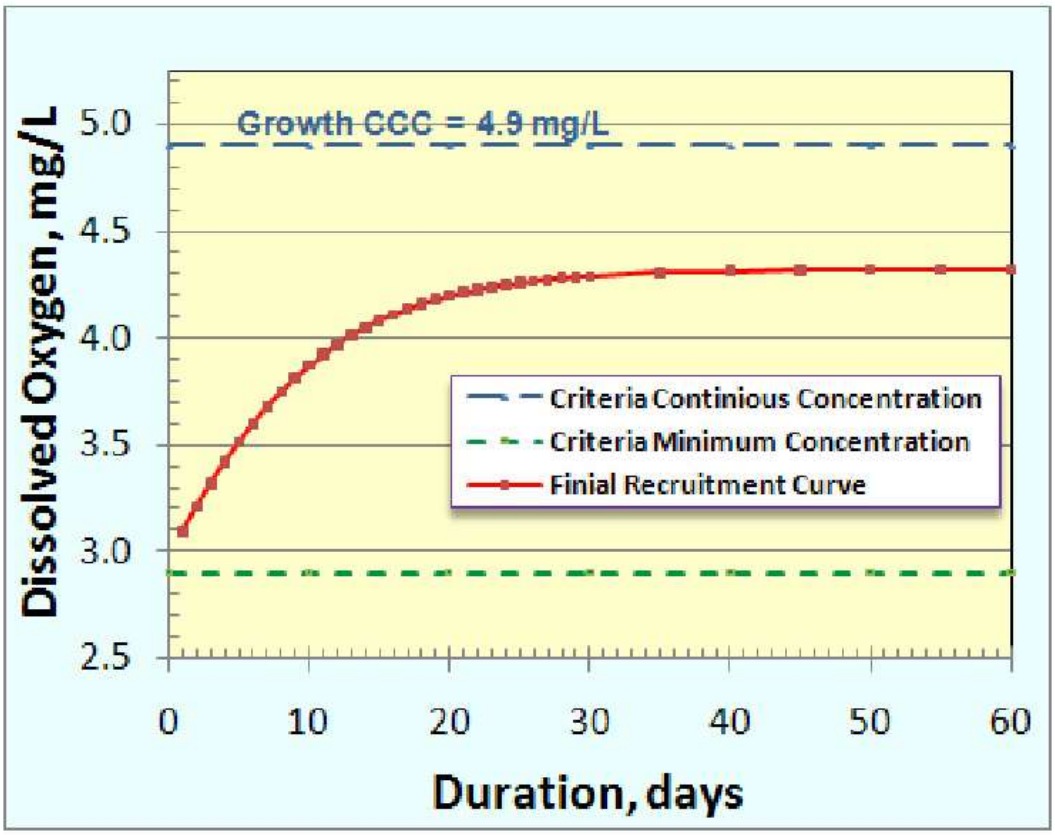

Figure 2-5. Three components to potential DO criteria as developed by FDEP (from FDEP, 2011).

The percent saturation criteria were derived by converting the DO concentrations used in the development of the concentration-based criteria to percent saturations using the concurrently measured water temperature and salinity data (FDEP, 2011). The proposed DO criteria could thus be expressed as follows (FDEP, 2011):

- The daily average DO concentrations shall not be below 41.7 percent saturation, and
- The 7- and 30-day average DO percent saturations shall not be below 51.0 and 56.5 percent, respectively.

3.0 Recommended Endpoints

A derivation of a potential chlorophyll *a* endpoint for McKay Bay was presented in Janicki Environmental (2005a), which considered the depth distribution of historical seagrass habitat in McKay Bay, and applied a living resource based approach to developing a chlorophyll *a* target for the McKay Bay/TBC system. The chlorophyll *a* target derived for the McKay Bay/TBC system was 19.4 µg/L (Janicki Environmental, 2005a). An update of the data analysis to include data through 2009 yielded similar results. Development of this target for the McKay Bay/TBC system is in keeping with the chlorophyll *a* targets developed and FDEP-approved for the remainder of Tampa Bay for protection and restoration of seagrass. Therefore, the recommended endpoint for the chlorophyll *a* threshold for McKay Bay is 19.4 µg/L annual average. The TBC

is presently dredge to a depth of 7 meters and would in no case be expected to target seagrass restoration. As such, for nutrients the target for

The TBEP has recently provided numeric nutrient criteria to FDEP for consideration for each segment of Tampa Bay (Janicki Environmental, 2011a). For Hillsborough Bay, one method of expressing the TN criterion is as a concentration-based criterion. In keeping with the federally-recognized TMDL TN loading targets for Tampa Bay, derived from the average annual 1992-1994 TN loads, the alternative numeric nutrient criterion in terms of TN concentration for Hillsborough Bay is the sum of the geometric mean concentration (1992-1994) plus one standard deviation (1992-2009). For Hillsborough Bay, this proposed alternative concentration-based TN criterion is 1.01 mg/L as the annual geometric mean. This TN level is deemed commensurate with the Hillsborough Bay chlorophyll *a* threshold of 15.0 µg/L. Establishment of a TN concentration endpoint in McKay Bay at this same level would ensure that TN concentrations in McKay Bay are protective of the McKay Bay chlorophyll endpoint of 19.4 µg/L. In addition, this TN concentration endpoint is protective of the downstream Hillsborough Bay segment. Therefore, the recommended endpoint for the TN concentration threshold for McKay Bay is 1.01 mg/L as an annual geometric mean.

While numerous DO criteria were outlined above, and alternative criteria are expected to be proposed by FDEP in the near future, the TMDL utilizes the existing criteria in conjunction with the IWR methodology for determination of compliance in order to assess the system compliance with DO.

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